models would then indicate that Pluto has a mean density of 1.2 g cm^{-3} . Second, CH_4 8 H_2O could have condensed out at nearer 70 K, internal heating in the planet leading to the outgassing of CH_4 which subsequently froze on reaching the surface.

The brightness of a planet is proportional to d^2a/R^2 where d is the diameter, a the albedo and R the distance between the planet and the observer. Rocky planets and satellites (Mercury, Mars, Moon) have low albedoes (0.056, 0.16, 0.067), frost covered satellites (Europa, Ganymede, Rhea, Dione and Tethys) have albedoes in the range 0.4 to 0.6. The presence of CH_4 frost on Pluto would put its albedo into this range too. Assuming that Pluto has an albedo of 0.4 and a mean opposition magnitude of 14.90, the diameter would be 3,300 km. An albedo of 0.6 implies a diameter of only 2,800 km. Both these values make Pluto smaller than our Moon (diameter 3,476 km).

But Pluto is not completely covered with CH_4 frost. If it were its brightness would be constant. Between 1952 and 1955 the magnitude varied asymmetrically by about 0.11 with a period of 6 d 9 h 17 min, this being the rotation period of the planet. The brightness fluctuations are caused by successive passages through the meridian of regions of differing reflectivity. Andersson and Fix (*Icarus* **20**, 279; 1973) found from observations made between 1971 and 1973, that the amplitude variation is now larger (0.22 mag) and the mean magnitude fainter (15.1). This is thought to be due to a change in the aspect of the planet as it moves round its orbit. The equatorial plane of Pluto is probably inclined at over 50% to orbital plane and the decrease in brightness is thus due to the sub-Earth point on the planet moving towards the equator during the past 40 yr, the polar regions having a higher albedo than the equatorial regions.

The mass of Pluto has been obtained from observations of the perturbations that this mass induces in the orbital motions of Uranus and Neptune. Seidelmann *et al.* (*Astr. J.* **76**, 488; 1971) obtained, for example, a value of 0.11 ± 0.02 Earth masses ($6.6 \times 10^{26} \text{ g}$). However Ash, Shapiro and Smith (*Science* **174**, 551; 1971) found that the value obtained for the mass of Pluto is extremely sensitive to the choice of perturbation data and parameter sets and that this mass cannot be determined with any certainty from this source.

If the density and size of the planet are known the mass can be easily estimated. The surface of Pluto inferred from the observations of Cruikshank *et al.* is exactly that to be expected for a large object which condensed at low

temperatures in the outer solar nebula. Its composition is probably dominated by frozen volatiles, just like most outer planetary satellites. (Remember there is a distinct probability that Pluto used to be a satellite of Neptune, but escaped during some encounter with Triton in the early times of the Solar System). If this is so its mean density is likely to be between 1 and 2 g cm^{-3} . Combining these with Cruikshank *et al.*'s values for the diameter (3,300 km if $a=0.4$, 2,800 km if $a=0.6$) gives mass values in the range 1.2×10^{25} to $3.8 \times 10^{25} \text{ g}$, about 1/250 the mass of Earth. This mass is much too small to perturb Uranus and Neptune in a measurable fashion, a conclusion which leads to two interesting consequences. First Clyde Tombaugh's discovery of Pluto must have been to a great extent fortuitous, the result of a diligent search and not an accurate, mathematically-derived, prediction as to the planet's position. Second if Pluto is not responsible for the perturbation of the orbits of Uranus and Neptune, something else must be; another planet or the cometary cloud perhaps? □

Palynology at Lucknow

from Peter D. Moore

The 4th International Palynological Conference was held at Lucknow on 29 December 1976–5 January 1977. The Proceedings are to be published.

Of particular interest at the conference were the accounts given of recent vegetation history in the tropics and subtropics, based upon studies of sub-fossil pollen grains stratified in peats, lake sediment and salt lake deposits. In contrast to the temperate areas of the world, the lower latitudes have been neglected and their recent environmental history is consequently little known. The work of J. R. Flenley (University of Hull) in New Guinea and A. P. Kershaw (University of Canberra) in north-eastern Australia has shown that tropical rain forest has not had the long uninterrupted Quaternary history which was once imagined. On the Atherton Tableland of Queensland, Australia, at an altitude of over 700 m, Kershaw has shown that the vegetation changed gradually from a microphyll vine forest to sclerophyllous woodland at about 25,700 b.p., which could have been due to increasing aridity or to the influence of early man, using fire. The development of rain

forest at the site did not occur until about 7,000 b.p.

Within India itself, the work of G. Singh (University of Canberra) and others has been of considerable value in elucidating the history of the deserts of western Rajasthan. The study of dry salt lakes in this area has shown that between 10,000 and 4,000 b.p. the sites were occupied by freshwater lakes and the pollen contained in these sediments demonstrates a development through *Artemisia* steppe to savannah vegetation with trees and shrubs. Desert encroachment followed this phase and is considered to be the product of climatic rather than cultural changes.

The argument about human involvement in recent vegetational changes is never easy to resolve. The presence of cereal pollen is often taken as evidence of human settlement and cultivation and therefore human potential for habitat modification. Cereal type pollen grains (40–50 μm) were found in the Rajasthan desert as far back as 9,300 b.p. and V. Mittre (Lucknow) reported even earlier finds of large Gramineae pollen in India. The Middle East records of cereal pollen were collated by A. Leroi Gourham (University of Paris); in Iran cereal pollen has been found in deposits going as far back as 60,000 b.p., thus demonstrating the existence of, presumably, the wild progenitors throughout the last glacial climatic episode. In Lebanon and Syria, herbaceous pollen was low during the forested times of the last glacial, but increased with forest decline (here cereal pollen is defined as being in excess of 60 μm).

The recognition of true cereal pollen, however, is not a matter over which all palynologists agree. Size criteria are most frequently used, but it is well known that mounting media can alter the sizes of pollen grains, they may swell in the course of time, and also some wild grasses have large pollen grains. E. Kohler and E. Lange presented some preliminary data on scanning electron microscope studies of grass pollen in an attempt to define cereals on more reliable morphological grounds. Only four genera (12 spp.) have been examined in detail so far, but four distinct types of sculpture have emerged. Sculpture alone however, does not provide a means of separating cereal from wild grass pollen. It is hoped that combinations of size, pore and sculpture type criteria will permit a more critical definition of pollen types within the Gramineae. Such a definition is vital to the furtherance of the study of primitive agriculture, its extents and its influence upon vegetation in the Middle East and India. □